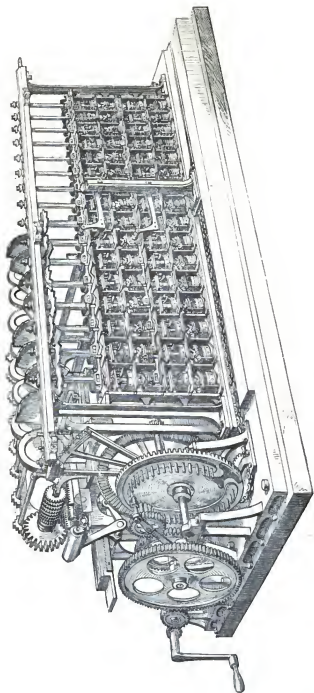


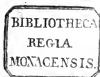
SPECIMEN TABLES
CALCULATED AND STEREOMOUNTED
BY
THE SWEDISH
CALCULATING MACHINE



SPECIMENS
OF
TABLES,
CALCULATED,
STEREOMOULDED, AND PRINTED
BY
MACHINERY.

LONDON:
LONGMAN, BROWN, GREEN, LONGMANS, AND ROBERTS,
PATERNOSTER ROW.

1857.



LONDON :

PRINTED (WITHOUT THE USE OF TYPES) BY C. WHITING, BEAUFORT HOUSE, STRAND.



TO
CHARLES BABBAGE, ESQ., F.R.S.,

&c. &c. &c.,

THESE PAGES ARE DEDICATED,

BY HIS SINCERE ADMIRERS,

GEORGE AND EDWARD SCHEUTZ.

Note at the foot of page 7.

In the next machine this rate of working may easily be increased ten-fold, so that twenty pages might be quietly *calculated* and *stereomoulded* whilst a compositor was merely "*setting up*" a single page. The addition of fifth and sixth, or indeed of any number of differences, would not occasion any diminution in the rate of working.

These facts are sufficient to show how vain it would now be to attempt reprints of any of the existing tables (even if uncertainty and error be disregarded) in any other way than by machinery.

The object of the Messrs. Schentz in the present machine was not great speed; and if they had attempted to do more than they actually have done, the reader of the foregoing little history will readily see, they, from mere want of means, would probably have produced no *working* machine at all.



PREFACE.

To those to whom this work is addressed it is unnecessary to point out the manifold advantages which have been derived in modern times from the various Numerical Tables now in the hands of the cultivators of science. The gigantic efforts that have led to the many important discoveries which have adorned the present century, would never have been made if these Tables had not existed. Astronomers, Navigators, Engineers, Actuaries, and indeed labourers in every department of science and the useful arts, could have made but little progress in their several vocations, had it not been for the resources supplied to them by those men of genius and of patience, who devoted their energies to this beneficial object : and when we contemplate the number and range of these Tables, and reflect upon the difficulties surmounted in their production, the time consumed, the labour employed, the capital expended, we cannot but regard with heartfelt gratitude and admiration those men who, without hesitation, and with an indomitable perseverance, devoted so many years of their lives to this irksome and herculean task ; and that too, be it remembered, at a time when very few of their contemporaries could estimate the value of the work they were accomplishing. Such men may indeed be called the Martyrs of Science !

While acknowledging, however, the deep debt of gratitude which is due to the intellect, the industry, and the self-sacrifice of a Napier or a Briggs, we must still admit that, notwithstanding the pains taken to insure accuracy, much still remains to be done. There is scarcely any numerical table, or perhaps it may more truly be said that no one table has ever been published, which does not contain errors more or less numerous ; and from a careful examination of a great number of existing tables, Mr. Babbage long ago arrived at the conviction that by

employing the means hitherto resorted to for constructing them, it was impossible ever to obtain more than an approximate degree of correctness. He accordingly conceived the project of constructing an engine, which, by mechanism alone, would not only compute tabular numbers, but at the same time also impress its results upon plates of copper or other material, from which they might be immediately printed on paper, so as entirely to supersede the use of ordinary types.

This happy idea of combining the act of mechanical computation of series of numbers with that of simultaneously printing them, was perfectly original; although, when once propounded, it appears obviously to be the only mode by which, at a moderate cost, and with an infinite saving of labour, numerical tables can be obtained, with the positive certainty of their being wholly exempt from error.

Such was the origin of the *Calculating Machine*, invented by Mr. Babbage, and which, from its operating by the successive additions of several orders of differences derived from any numerical series, having all its terms connected by some analytical law, he denominated THE DIFFERENCE ENGINE.

The only analogous contrivances which had been effected, or even proposed, prior to Mr. Babbage's Difference Engine, were designed for the performance merely of single arithmetical operations of the most elementary kind, such as addition, subtraction, multiplication, and division—the very operations which numerical tables are intended to supersede, by sparing the inquirer the trouble of performing them either by the labour of the head or the manipulations of a machine, and presenting the results to his eye in the columns of a printed page.

The Difference Engine of Mr. Babbage had from time to time been cursorily noticed in several periodicals, when a circumstantial and elaborate disquisition on its merits and construction appeared in the *Edinburgh Review* for July, 1834. It was from the perusal of this article that Mr. George Scheutz, at that time the editor of a technological journal in Stockholm,

derived the first conception of constructing a machine for effecting the same purpose as that of Mr. Babbage, namely, that of calculating and simultaneously printing numerical tables.* But after he had satisfied himself of the practicability of the scheme, by constructing various models, composed of wood, pasteboard, and wire, he postponed to a future period the further prosecution of the design.

Three years afterwards, in the summer of 1837, his son, Mr. Edward Scheutz, at that time a student in the Royal Technological Institute at Stockholm, offered to his father to construct a working model in metal, on condition that he might have the use of a particular work-room in his father's house, as well as of a lathe and other necessary tools. With these implements he commenced the work, and during the summer vacation had so far completed it, as to demonstrate the feasibility of the scheme, and its applicability to the practical purposes for which it was designed.

Matters being so far advanced, his father made application to the Government on the 30th of October in the same year, for their sanction and assistance in the completion of the plan. To this application a negative answer was returned on the 21st of February in the following year.

Not discouraged by this refusal, Mr. E. Scheutz continued to employ his time on the model, holding frequent discussions with his father relative to the improvements in the original conception; sometimes the one and sometimes the other suggesting expedients for overcoming the difficulties that presented themselves. After many trials and many alterations, the calculating apparatus was, in the year 1840, so far completed, that it correctly calculated series with terms of five figures and one difference, also of five figures. On the 29th of April, 1842,

* The article in the *Edinburgh Review* above referred to also suggested to Mr. Alfred Deacon the contrivance of a difference engine for the same purpose, but on a plan of construction very different. This machine is still in existence, although not in a finished state; it was intended to calculate consecutive numbers to twenty figures, with three orders of differences; but, on account of the expense, printing the result was not contemplated.

the model was extended so as to calculate similar series with two and three orders of differences.

The following year, 1843, the printing apparatus, and all the other parts of the model, were in readiness for the inspection of the Royal Swedish Academy of Sciences. After several trials, a certificate was obtained on the 18th September, 1843, signed by Baron Jacob Berzelius, Secretary of the Academy ; N. H. Selander, Astronomer of the Academy ; and E. B. Lilliehöök, R. N., Professor of Natural Philosophy in the Royal Military Academy at Marieberg.

From this certificate the following passages are extracted :—

“The apparatus in question is composed of three parts.

“1st. The Calculating Machine.—It cannot compute series of a higher degree than the third, nor does it give complete terms exceeding five figures ; but in the nature of the mechanism, there is nothing to prevent its extension to the working of series of any degree whatever, and to terms of as many figures as the purpose may require.

“2nd. The Printing Machine.—Every term given by the calculating apparatus is expressed by printed figures, closely arranged in lines, as in a printed table, the lines being impressed on some softer material, adapted to receive galvanoplastic or stereotyped copies. All the lines succeed each other very correctly in the same vertical column.

“3rd. The Numbering Machine.—With the printing machine, another apparatus is combined, which prints the arguments before every term. The machine is put in motion by turning the handle of a winch, by means of which, and without further manipulations, the calculation, as well as the printing and arranging of figures and lines, are effected.”

The inventors sought for orders in various countries, making use of the above certificate as a recommendation ; but, meeting with no success, the model remained shut up in its case during the ensuing seven years.

But in the year 1850, December 26th, another inspection was made by a committee of the Royal Academy of Sweden,

consisting of General Baron Fabian Wrede, Chief of the Royal Military Academy at Marieberg ; and the late P. A. Wallmark, R.N., Director of the Royal Technological Institute of Stockholm.

In the beginning of the following year, 1851, January 28, Mr. George Scheutz made a fresh application to the Government, to obtain from them the means of carrying the plan into full execution, by the construction of a larger and still more improved machine. His request was first referred to the judgment of the Academy of Sciences, which then advised the Government to consent to the application, because, as their Report says, "the Messrs. Scheutz had devoted many years of labour to this invention, which, without the least doubt, would be useful to science ; and had incurred expenses, which, with relation to their resources, were very considerable ; and that Mr. Scheutz, sen., had for a long time, without assistance from the public, published many useful works in his native country, relating to industrial progress."

The decision of the Government, given on the 29th April, was, that there were no public funds at their disposal for the object in question.

In the Diet of 1851, Mr. A. M. Brinck, a merchant, and member of the Diet for Stockholm, moved that a national recompense should be given to the inventors. The motion was acceded to, on condition that the money should be paid to Messrs. G. and E. Scheutz after his Majesty the King had, on due examination, given it as his opinion that the machine was completed and answered its purpose. The inventors now sought to anticipate the reward, in order to have the means of completing the invention, and their petition was granted on the 24th October, 1851, on condition that the money was to be refunded if the machine was not completed before the end of the year 1853, or if, when completed, it was not found to answer its purpose.

In consequence of these limitations, the inventors were obliged, in the first instance, to procure a guarantee for the repayment, in case of failure. Partly by their own exertions, and partly by the kind assistance of some members of the

Swedish Academy, they were fortunate enough to collect a list of subscribers, each of whom rendered himself responsible for that part of the amount which was annexed to his name. The names of the subscribers are found in the subjoined note ; * and the author of this little book embraces this opportunity of expressing to them, in the names of the inventors of the machine, their gratitude for the means thus afforded of bringing it into its present improved state. Without such patronage, indeed, the machine would probably never have been completed, nor these tables produced.

The first working drawing of the new machine was finished on the 1st of February, 1852, and the machine itself was completed before the end of October, 1853.

The machine thus completed differs in many parts from the first model, which was confined in its range to the decimal scale, and could neither produce tables containing hours or degrees, minutes and seconds, nor effect the requisite corrections in the last printed figure. For the suggestion of these important improvements, the inventors are indebted to General Baron Fabian Wrede, who was one of the most zealous promoters of the undertaking. The machine was constructed in conformity with the drawings of Mr. Edward Scheutz, and under his immediate superintendence, at the manufactory of Mr. C. W. Bergström, at Stockholm; and when all the parts were finished, and finally put together, the new machine performed its work so perfectly, that the first trials required no alteration whatever. In the Report to H. M. the King of Sweden, the Royal Academy not only declared that the machine answered its purpose, but at the same time expressed its conviction, founded on the evidence of facts, that the expenditure for the completed machine had far exceeded the sum awarded as the national recompense. His Majesty then proposed to the Diet to give

* E. F. Berg	J. Falkenholm	P. W. Lundgren
C. F. Bergstedt	N. Grafström	B. O. Nycander
J. W. Bergström	L. J. Hierta	P. Siljeström
C. Crasselt	G. Lallerstedt	P. E. Swedbom
Eklund	Lovén	J. Wahlström

the inventors an additional recompense, of the same amount as the former one, which proposition was agreed to, the inventors receiving an official notice of this decision in their favour, from the Royal Academy of Sciences, on the 11th of August, 1854.

It was during the three last months of the same year, that the inventors visited England and France. On their arrival in London, they met with one of their countrymen, Count P. A. Sparre, by whom they were introduced to Messrs. Bryan Donkin & Co., Civil Engineers, who allowed the two foreigners to exhibit the machine at their manufactory in Bermondsey. It was here that they became acquainted with Mr. William Gravatt, F.R.S., Civil Engineer, who took a very warm interest in the invention, gave notice to the Royal Society of the arrival of the machine, and showed and explained it to several of the most eminent members of that learned body—namely, Colonel Edward Sabine, Doctor P. M. Roget, Professors Faraday, Hind, Stokes, Wheatstone, Miller, and several others.

After the departure of the inventors, the Royal Society, at Mr. Gravatt's request, most kindly allowed the machine to remain in one of their apartments in Somerset House, where Mr. Gravatt had also the kindness to work it, and to explain its mechanism on many occasions to the Fellows of that illustrious Society and other visitors. On the 29th of January, 1855, it was honoured by the inspection of His Royal Highness Prince Albert.

The machine was in the same year conveyed under the care of Count Sparre, to Paris, and placed in the Great Exhibition, where Mr. Gravatt again had the kindness to work and explain it to many scientific gentlemen. The jury to which it was referred, composed of distinguished persons of all nations, after a full examination, unanimously awarded the Gold Medal to the inventors, who received it publicly through the hands of His Royal Highness the Prince Charles, in the Royal Palace of Stockholm, on the 21st of April, 1856. Some time previously, Mr. Scheutz, sen., was elected a Member of the Swedish Academy of the Third Class for the Science of Mechanics; and

on the 28th of April he was made a Knight of the Order of Wasa.

A letter from Mr. Bryan Donkin, of the 5th June, 1856, induced Mr. E. Scheutz again to make a short visit to London, where he had the gratification of meeting those friends whose interest in the invention had remained unabated.

By the advice of Mr. Gravatt, to whom the inventors were already under such deep obligation, it was resolved that the machine should again be brought over to England, and, as a last attempt, that an endeavour should be made to obtain an acknowledgment of the practical usefulness of the invention by the publication of a collection of specimens of numerical Tables computed and printed by the machine. Mr. Gravatt had also the kindness to set apart a room in his own house for the performance of this work, and offered to promote the undertaking in every way. The inventor, now animated with fresh hopes, returned to France in order to fetch the machine, and it was during his stay there that he had the honour of showing the engine at work in the Imperial Observatory.

After Mr. E. Scheutz's return to London, as soon as the machine was put in order, and he had consulted Mr. Babbage and Mr. Gravatt with regard to the specimen Tables to be printed, this work was commenced, the calculations for setting the machine being made partly by Mr. Gravatt, according to formulæ of his own, and partly by Mr. E. Scheutz, after formulæ which General Baron Fabian Wrede had the kindness to give him on his departure from Sweden.

Meanwhile, what had been passing in London and in Paris had not escaped the notice of Professor B. A. Gould, of the Dudley Observatory, Albany, in the United States, who, conceiving the possibility of procuring purchasers for the machine in America, exerted himself in the most liberal and enlightened spirit to accomplish this object. The inventors had so many times seen their hopes blighted, that they did not expect that anything decisive would result from this new attempt; but they found themselves mistaken, for, after some time, they received information from Professor Gould that the terms they had pro-

posed had been accepted; the machine, therefore, now belongs to the Dudley Observatory, at Albany, being a gift to that Observatory from an enlightened and public-spirited merchant of that city, John Fr. Rathbone, Esq.

In the course of their career, the inventors have had to go through many difficulties; but they have also been amply rewarded by the friendship and sympathy, which so many good and noble-minded men have manifested towards them, and by the certainty they now possess, that the object for which they have so long and so severely toiled, will not be lost. They believe, also, that if this limited collection of specimens should be deemed not sufficient to prove the practical usefulness of the invention, it will soon be followed by other proofs of greater importance, printed by the astronomers of the Western World; and that the individual to whom they have with gratitude and regard dedicated this little work, will then be further known for what he truly is—namely, one of the benefactors of mankind, and one among the noblest and most ingenious of the sons of England.

The drawing here given, is from an engraving kindly lent by the proprietor of the *Illustrated London News*, and exhibits the machine at a time when it has just completed the operation of stereotyping a result extending to eight places of figures.

It may be as well to premise that the size of the whole machine, when placed on its proper stand and protected by its cover, is about that of a small square pianoforte.

The calculating portion of the machine, which appears in the front of the drawing, consists of a series of fifteen upright steel axes, passing down the middle of five horizontal rows of silver-coated numbering rings, fifteen in each row, each ring being supported by, and turning concentrically on its own small brass shelf, having within it a hole rather less than the largest diameter of the ring. Round the cylindrical surface of each ring are engraved the ordinary numerals from 0 to 9, one of which, in each position of the ring, appears in front, so that the successive numbers shown in any horizontal row of rings may be read from left to right, as in ordinary writing.

The upper row exhibits the number or answer resulting from

the calculation to fifteen places of figures, the first eight of which the machine stereotypes. The numbers seen on the second row of rings constitute the first order of differences, also to fifteen places of figures, if that number be required; and the third, fourth, and fifth row of rings, in like manner, exhibit the second, third, and fourth orders of differences. Any row can be set by hand, so as to present to the eye any number expressed according to the decimal scale of rotation; such as the number 987654321056789, the first eight figures of which, if in the uppermost row, would, on being calculated by the machine, be immediately stereotyped. But by simply changing a ring in each of two of the vertical columns, the machine can be made to exhibit and to calculate numbers expressed in the mixed senary system of notation, as in that of degrees, minutes, seconds, and decimals of a second. Thus, for instance, if the result 874324687356402 were indicated in the upper row of rings, it would be stereotyped 87 degrees 43 minutes 24.69 seconds. While this process is going on, the argument proper to each result is at the same time also stereotyped in its proper place; nothing more being required for that purpose than to set each row of figure rings to differences previously calculated from the proper formula, and to place a strip of sheet lead on the slide of the printing apparatus; then, by turning the handle (to do which requires no greater power than what is exerted in turning that of a small barrel-organ), the whole table required is calculated and *stereomoulded in the lead*. By this expression is meant that the strip of lead is made into a beautiful stereotype mould, from which any number of sharp stereotype plates can be produced ready for the working of an ordinary printing press. At the average rate of working the machine, 120 lines per hour of arguments and results are calculated and actually stereotyped, ready for the press. It is found on trial that the machine calculates and stereotypes, without chance of error, two-and-a-half pages of figures in the same time that a skilful compositor would take merely to set up the types for one single page.

The appearance of the tables would have been much improved had the machine been provided with better steel figure-wheels, the reason for not adopting which alteration may be gathered from the little historical sketch herein given.

In order to limit the size of this little book, the specimens given are neither so numerous nor so extensive as was at first intended. A great number of tables were suggested,* but they all so evidently came within the power of this machine, and as mere repetition was to be avoided, the short specimens Nos. 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 were considered sufficient as examples of tables perfectly easy with this machine, which happens to be limited to four orders of differences.

Specimen 12, the radius vector of Venus, and 13, the Sun's longitude for every twenty-four hours, are examples of calculations also easily within the power of four differences, but of which the number of terms obtainable at such wide intervals at one setting is considerably less than in the first-mentioned specimens. If, however, we wanted the Sun's longitude, or the radius vector of Venus, or any similar table, for intervals of every three hours for instance, it is evident that the machine could produce at each setting a table of eight times the extent of the specimens given.

In specimen 14, the logarithm of the Earth's radius vector, and still more in specimen 15, the logarithm of the distance between the Earth and Mars, in consequence of the wideness of the intervals, the want of more than four orders of difference, or the addition of some such contrivance as Mr. Babbage has alluded to in his letter to Sir H. Davy, July 3rd, 1823, begins to be felt. Should, however, five places of decimals be considered sufficient, double the number of terms could be produced in one setting in each of the specimens 14 and 15; or, if the intervals were smaller, the same remark would apply to these

* Such as Second Logarithms, Anti-logarithms, Powers of Sines, &c., Natural Sines, &c., Life Annuity Tables, Interest Tables, Difference of Latitude and Departure, Mensuration, Flow of Water in Canals and through Pipes, Earthwork Tables, &c.

specimens as to specimens 12 and 13; and it must be borne in mind, that, however short may be the range in this machine at any one setting, the answers are calculated indifferently in either the decimal or in the mixed sennary scales, and stereomoulded at the same time without chance of error.

Again, if we set the machine to the numbers shown in the left-hand column below,

1	16	81	
1	15	65	175
14	50	110	
12	36	60	84
24	24	24	

24 will be added to 12 and *simultaneously* 14 to 1, giving respectively 36 and 15, and then 36 will be added to 14 and *simultaneously* 15 to 1, giving respectively 50 and 16, and so on; the machine as thus set producing the squares of the squares, or the fourth powers of the natural numbers as long as we please to turn the handle.

In the last example the machine is supposed to be stopped at a half-stroke, with only the *odd differences* 84 and 175 in the fourth column. Now, if we re-set the machine (changing the sign of these odd differences) as shown in the left-hand column below,

81	16	1	
-175	-65	-15	-1
110	50	14	
-84	-60	-36	-12
24	24	24	

we shall have $24 + -84 = -60$, and simultaneously $110 + -175 = -65$ for the first half-stroke, and $-60 + 110 = 50$, and simultaneously $-65 + 81 = 16$ for the second half-stroke, and so on. That is, if we in this way change the signs of the odd differences, the machine will, so to speak, go backwards, and that as long as we please to turn the handle.*

A negative number is expressed in the machine by its complement; thus, if to 56789, we wish to add, say minus 67 (that is, in fact, to subtract 67), we set the machine to add 99933 to 56789, thus :—

	56789		56789
less	67	added to	99933
gives	56722	gives	156722

but as in the machine there is purposely no figure-wheel to receive the left-hand 1, it is thrown (so to speak) into the air, and the machine shows and stereomoulds 56722 as it ought to do.

* In this way we can always make the machine itself show us the differences with which it was set.

This particular machine is capable of expressing u and its differences as far as the fourth order, to fifteen places of figures; but we may have to deal with differences of more than fifteen places, although we only require four, five, six, seven, or at most eight places of figures, to be printed as the tabular value of u .

Now if the machine be worked, so as to give very many values of u , it is evident that the omission of the 16th, &c., places of figures might begin to tell in the tabulated result.

To avoid this, it is necessary to know how many values of u we may obtain without an error, in the lowest figure of the printed result.

For this purpose, if we, considering what has gone before, imagine the machine set, as shown in the first column below, putting in only one value Δ , and that in the fourth order of differences,

1st	2d	3d	4th	5th	n^{th} Terms.
0	0	1Δ	5Δ	$15\Delta \dots \frac{n-2}{1} \cdot \frac{n-1}{2} \cdot \frac{n}{3} \cdot \frac{n+1}{4} \Delta$	
0	0	1Δ	4Δ	$10\Delta \dots \frac{n-2}{1} \cdot \frac{n-1}{2} \cdot \frac{n}{3} \cdot \Delta$	
0	1Δ	3Δ	6Δ	$10\Delta \dots \frac{n-1}{1} \cdot \frac{n}{2} \cdot \Delta$	
0	1Δ	2Δ	3Δ	$4\Delta \dots \frac{n-1}{1} \cdot \Delta$	
Δ	Δ	Δ	Δ	Δ	Δ

we should, in the manner in which the machine combines the differences (that is, always in *simultaneously formed couples*), obtain the 2nd, 3rd, 4th, 5th, and n^{th} columns, the coefficients of Δ being necessarily and obviously *figurate numbers* of the various orders (in this case up to the 5th order) but with the 2nd and 3rd figurate numbers *set forward one term*, and the 4th and 5th figurate numbers *set forward two terms*—the law for any machine taking in any order of differences being evident. We immediately see that if we were to set in such a machine $\Delta^0 \Delta^1 \Delta^2 \Delta^3 \Delta^4$, putting P_n for the n^{th} printed number we shall get

$$P_n' = \Delta^0 + \frac{n-1}{1} \Delta^1 + \frac{n-1}{1} \cdot \frac{n}{2} \Delta^2 + \frac{n-2}{1} \cdot \frac{n-1}{2} \cdot \frac{n}{3} \Delta^3 + \frac{n-2}{1} \cdot \frac{n-1}{2} \cdot \frac{n}{3} \cdot \frac{n+1}{4} \Delta^4$$

Whence we see that if the error from leaving out the 16th, &c., figures, be α in the first difference, and β, γ, δ , respectively, in the 2nd, 3rd, and 4th differences (putting e the error in P_n), we should have e always less than $n \alpha + \frac{n^2}{2} \beta + \frac{n^3}{6} \gamma + \frac{n^4}{24} \delta$.

Now as we may always set the machine to $u \pm \frac{1}{2} \epsilon$ instead of u , (thereby halving the effect of any error) we may, even when working with all the four differences, put practically $\epsilon = \frac{n^4}{48} \delta$.*

If m be the number of places required in the table, it is usual not to allow a greater error than ± 5 in the $m + 1^{\text{th}}$ place. Now, the *greatest value* δ can have is (less than) 5×10^{-16} , whence we readily see that we may put $n^4 = 48 \times 10^{15-m}$. So that if, for instance, we required the machine to print 8 places correctly, we have $n^4 = 48 \times 10^7 = 480\,000\,000$ or $n = 148$ for the number of values of u that we can print in each direction.

If we wish to print only 7 places correctly, we have $n^4 = 48 \times 10^6$ or $n = 263$.

If we wish to print only 5 places correctly, we have $n^4 = 48 \times 10^{10}$ or $n = 832$, so that in this case we may print about 800 terms for each forward and for each backward working of the machine, or together about 1600 terms.

The following method of finding proper differences with which to set the machine (founded on the 5th lemma of the 3rd book of the Principia) is general, and extremely easy in practice. Let $u_x = u_0 + ax + bx^2 + cx^3 + dx^4$ now putting x successively $= 0 \pm 1$ and ± 2 we get

	1 st Differences.	2 nd Differences.
$u = u_0 - 2a + 4b - 8c + 16d$	$a - 3b + 7c - 15d$	
$u = u_0 - a + b - c + d$	$a - b + c - d$	$2b - 6c + 14d$
$u = u_0$		$2b + 2d$
$u = u_0 + a + b + c + d$	$a + b + c + d$	$2b + 6c + 14d$
	$a + 3b + 7c + 15d$	
$u = u_0 + 2a + 4b + 8c + 16d$		
3 rd Differences.	4 th Difference.	
$6c - 12d$	$24d$	
$6c + 12d$		

* Instead of $\frac{n^4}{48}$ we really use $\frac{n^4 - 2n^3 - n^2 + 2n}{48}$

Whence $d = \frac{1}{2} \Delta^4 u_{-2}$ $c = \frac{1}{6} \Delta^3 u_{-2} + 2d$ $b = \frac{1}{2} \Delta^2 u_{-1} - d$ and $a = \Delta^1 u_{-1} + \frac{1}{2} \Delta^2 u_{-1} - c$.

Now, if $n-1$ be the number of terms to be interpolated between u_0 and u_{+1} , u_{-1} , and $u_{\pm 2}$, &c.; putting $\frac{1}{n} = x$ we get immediately

$$\begin{aligned}\Delta^4 u_{-2x} &= 24dx^4 \\ \Delta^3 u_{-2x} &= 6(cx^3 - 2dx^4) \\ \Delta^2 u_{-x} &= 2(bx^2 + dx^4) \\ \Delta^1 u_{-x} &= ax - bx^2 + cx^3 - dx^4\end{aligned}$$

With which differences we can set the machine and tabulate forwards from u through u_1 to u_2 and by changing the sign of the odd differences in the manner before shown, we can tabulate backwards from u through u_{-1} to u_{-2} , and this without knowing even the form of the function we are tabulating, it being sufficient that we have five values taken at equal intervals.*

Now u (the function of x , we may have to consider), may not have the 4th, nor indeed any order of differences constant, and to see the consequences of this let us compare (as in most cases will be amply sufficient) the value of the u_x derived from four orders of differences (which I write ${}^4u_x$) with the value of u_x derived from six orders of differences (which I write ${}^6u_x$).

In the equation $u_x = u_0 + a x^1 + b x^2 + c x^3 + d x^4 + e x^5 + f x^6$, putting x successively 0 + 1, ± 2 , ± 3 , in the manner before shown, we get

$$\begin{aligned}f &= \frac{1}{720} \Delta^6 u_{-3} \\ e &= \frac{1}{120} \Delta^5 u_{-3} + \frac{1}{720} \Delta^6 u_{-3} \\ d &= \frac{1}{24} \Delta^4 u_{-2} - \frac{1}{144} \Delta^5 u_{-3} \\ c &= \frac{1}{6} \Delta^3 u_{-2} + \frac{1}{12} \Delta^4 u_{-2} - \frac{1}{24} \Delta^5 u_{-3} - \frac{1}{48} \Delta^6 u_{-3} \\ b &= \frac{1}{2} \Delta^2 u_{-1} - \frac{1}{24} \Delta^4 u_{-2} + \frac{1}{180} \Delta^6 u_{-3} \\ a &= \Delta^1 u_{-1} + \frac{1}{2} \Delta^2 u_{-1} - \frac{1}{6} \Delta^3 u_{-2} - \frac{1}{12} \Delta^4 u_{-2} + \frac{1}{30} \Delta^5 u_{-3} + \frac{1}{60} \Delta^6 u_{-3}\end{aligned}$$

* The way I use the above formula in practice, is to begin, at the right-hand side of properly ruled paper, with the 4th differences, performing the calculations line by line in the order shown in the example given in page 8. In order to enable us to work always forwards from u through u_{-1} to u_1 (which may sometimes be convenient) I have arranged a formula and given under it an example in page 9.

Now suppose we put

$u_0 + ax + bx^2 + cx^3 + dx^4 + ex^5 + fx^6 = u_0 + \alpha x + \beta x^2 + \gamma x^3 + \delta x^4$
rigidly only when $x = 0 \pm 1$ and ± 2 , but within a certain
degree of approximation only when x has any other values;
we get directly

$$\delta = \frac{1}{24} \Delta^4 u_{-2} \quad \gamma = \frac{1}{8} \Delta^3 u_{-2} + \frac{1}{12} \Delta^4 u_{-2} \quad \beta = \frac{1}{2} \Delta^2 u_{-1} - \frac{1}{24} \Delta^4 u_{-2}$$

$$\alpha = \Delta^1 u_{-1} + \frac{1}{2} \Delta^2 u_{-2} - \frac{1}{8} \Delta^3 u_{-2} - \frac{1}{8} \Delta^4 u_{-2}$$

Whence ${}^6u_x - {}^4u_x = \frac{1}{720} \Delta^6 u_{-3} x^6 + (\frac{1}{120} \Delta^6 u_{-3} + \frac{1}{240} \Delta^6 u_{-3}) x^5$
 $- \frac{1}{144} \Delta^6 u_{-3} x^4 + (\frac{1}{24} \Delta^6 u_{-3} + \frac{1}{8} \Delta^6 u_{-3}) x^3$
 $+ \frac{1}{180} \Delta^6 u_{-3} x^2 + (\frac{1}{36} \Delta^6 u_{-3} + \frac{1}{60} \Delta^6 u_{-3}) x$
 $= \frac{1}{720} \Delta^6 u_{-3} \{x^6 + 3x^5 - 5x^4 - 15x^3 + 4x^2 + 12x\} +$
 $\frac{1}{144} \Delta^6 u_{-3} \{x^5 - 5x^3 + 4x\}$

Now if we attend to the spirit of Newton's lemma, we see
that the errors arising from the use of four differences, when we
ought to use six differences, must be nearly maximums when
 $x = \pm \frac{1}{2} \pm \frac{3}{2}$, and putting in our equation these values of x , we
have rigidly

$$\begin{aligned} {}^6u_{\frac{1}{2}} - {}^4u_{\frac{1}{2}} &= \frac{3}{256} \Delta^5 u_{-3} + \frac{7}{1024} \Delta^6 u_{-3} \\ {}^6u_{-\frac{1}{2}} - {}^4u_{-\frac{1}{2}} &= -\frac{3}{256} \Delta^5 u_{-3} - \frac{5}{1024} \Delta^6 u_{-3} \\ {}^6u_{\frac{3}{2}} - {}^4u_{\frac{3}{2}} &= -\frac{7}{256} \Delta^5 u_{-3} - \frac{61}{1024} \Delta^6 u_{-3} \\ {}^6u_{-\frac{3}{2}} - {}^4u_{-\frac{3}{2}} &= \frac{7}{256} \Delta^5 u_{-3} + \frac{7}{1024} \Delta^6 u_{-3} \end{aligned}$$

Or, in practice, the maximum *half error* may be taken as

$$\begin{aligned} .001 (6 \Delta^5 u_{-3} + 3 \frac{1}{2} \Delta^6 u_{-3}) &\text{ between } u_0 \text{ and } u_1 \\ .001 (-6 \Delta^5 u_{-3} - 2 \frac{1}{2} \Delta^6 u_{-3}) &\text{ between } u_0 \text{ and } u_{-1} \\ .001 (-14 \Delta^5 u_{-3} - 10 \frac{1}{2} \Delta^6 u_{-3}) &\text{ between } u_1 \text{ and } u_2 \\ .001 (14 \Delta^5 u_{-3} + 3 \frac{1}{2} \Delta^6 u_{-3}) &\text{ between } u_{-1} \text{ and } u_{-2} \end{aligned}$$

and these errors will of course be kept out of our tables;
that is, we shall use one place of figures less than that which
would be affected.

As an easy (and certainly a very favourable) example of the power of the machine, let us with it calculate a table of the Logarithms of the natural numbers up to 10,000, to five places of decimals. We must first actually calculate by any of the known methods the logarithms of 2, 3, 7, 11, 17, and 19, to seven places of decimals, from which we shall immediately obtain the logarithms of

10	20	40	80
11	22	44	84
12	24	48	88
13	26	52	92
14	28	56	96
15	30	60	100
16	32	64	
17	34	68	
18	36	72	
19	38	76	

To which, applying the formulæ just given, we, by ten easy calculations,* and by ten forward and ten backward settings of the machine, shall obtain a stereomoulded table up to 10,000.

The time occupied by the machine at its ordinary rate of working (namely, 120 numbers per hour), would be seventy-five hours; the ten plus and minus (say twenty) settings would not take up quite two hours; the calculations by the formulæ given of the proper differences to be set in the machine, could not cause a delay of two hours, the time taken (exclusive of the preliminary calculation of the logarithms of 2, 3, 7, 11, 17, and 19) being altogether about seventy-nine, or say eighty hours.

* See next page.

$$\left\{ \begin{array}{l} \Delta^1 u + \frac{1}{2} \Delta^2 u - c = a \\ a x - b x^2 + c x^3 - d x^4 = \Delta^1 u_{-2} \end{array} \right\} \Delta^2 u \cdot \frac{1}{2} - d = b \quad \left\{ \begin{array}{l} (\Delta^2 u + \frac{1}{2} \Delta^4 u) \cdot \frac{1}{2} = c \\ (c \cdot x^3 - 2 d x^4) \cdot 6 = \Delta^2 u_{-2} \end{array} \right\} \Delta^3 u \cdot \frac{1}{6} - \frac{1}{12} = d$$

As an example, take $u_0 = \log. 3000 = .4771213$; $N = 200$. On ruled paper the calculation would appear as below:

1st Diff. $x = 10 \div 2$	2nd Diff. $x = 10 \div 4$	3rd Diff. $x = 10 \div 8$	4th Diff. $x = 10 \div (4 \times 4)$
$\begin{array}{r} + \\ 299633; \\ 9673; \\ 289960; \\ 434; 666667 = c \\ 289525; 333333 = a \\ 1447; 62666667 = ax \\ 24128333 = bx^2 \\ 5433 = cx^3 \\ 1 = dx^4 \\ -0001447; 86800434 = \Delta^1 \end{array}$	$\begin{array}{r} - \\ 19346; \\ 9673; \\ 21; 666667 = d \\ 9651; 33333 = b \\ 241283333 = bx^2 \\ 1482566666 \\ 27 = 2dx^4 \\ 482566693 \\ 99; 51743330, 7 = \Delta^2 \end{array}$	$\begin{array}{r} + \\ 2868; \\ 260; \\ 2608; \\ 434; 66667 = c \\ 543333 = cx^2 \\ 271 = 2dx^4 \\ 543604 \\ 00; 00032616, 24 = \Delta^3 \end{array}$	$\begin{array}{r} - \\ 520; \\ 260; \\ 21; 6667 = d \\ 5417 \\ 1354 = dx^4 \\ 2708 = 2dx^4 \\ 32496 \\ 99; 99999967, 504 = \Delta^4 \end{array}$
$\begin{array}{r} 000144738543765 \\ 999855261456235 = -\Delta^1 \end{array}$	$\begin{array}{r} 00; 00032585 \\ 99; 99967417 = -\Delta^2 \end{array}$		

From which we get Logs. 2600, 2601...3400 or 800 Logarithms.

The calculation for the 1st Diff. is extended five places of decimals further than is necessary, in order to show how cx^3 and dx^4 would come in if they were required, and for a similar reason the calculations for the 2nd and 3rd Diff. are extended respectively four and three places. The semicolon here marks off the 7th place of decimals, and the comma the 15th or last figure in the machine.

4th Diff.

$$\Delta^4 \frac{1}{-2N^4}$$

3rd Diff.

$$\left(\Delta^3 - \frac{1}{2} \Delta^4 \right) \frac{1}{N^3} - \Delta^4 \left(\frac{1}{N^3} + \frac{1}{2N^4} \right) \quad (A)$$

2nd Diff.

$$\begin{aligned} & \Delta^2 \frac{1}{N^2} \\ & - \left(\Delta^2 - \frac{1}{2} \Delta^4 \right) \frac{1}{N^2} \quad (F) \\ & + \left(\Delta^2 - \frac{1}{2} \Delta^4 \right) \left(\frac{1}{N^2} + \frac{1}{2N^3} \right) \frac{N+1}{3} \quad (E) \\ & - \Delta^4 \left(\frac{1}{N^2} + \frac{1}{2N^3} \right) \frac{N+1}{3} \frac{N+1}{4} \quad (C) \end{aligned}$$

$$+ \left(5\Delta^4 \frac{1}{N^2} + \Delta^4 \frac{1}{-2N^4} \right) \frac{1}{12} \quad (B)$$

As an example let $u = 352 \quad 38 \quad 3 \cdot 71$, the Sun's Longitude March 13th, 1858, to tabulate the Longitude for March 13th, 14th, 15th....25th. Putting $N = 6$, we have as below :—

$$u = 352 \quad 38 \quad 3 \cdot 71$$

1st Diff.

$$\begin{aligned} & + \\ & 21488 \cdot 500 = \Delta^1_1 \\ & 40 \cdot 1 \end{aligned}$$

$$21528 \cdot 6$$

$$3588 \cdot 100$$

$$14 \cdot 81 F$$

$$3602 \cdot 581$$

$$1278 E$$

$$3601 \cdot 503$$

$$246 C$$

$$3601 \cdot 057$$

2nd Diff.

$$\begin{aligned} & 804 \cdot 000 = \Delta^2_1 \\ & 1356 \cdot 7 \\ & 22278 \end{aligned}$$

$$5056 D$$

$$17222$$

$$1397 B$$

$$15825$$

$$\begin{aligned} & 99 \quad 59 \quad 584 \cdot 175 = \Delta^1 \\ & \underline{\underline{99 \quad 59 \quad 598 \cdot 555 = \Delta^2}} \end{aligned}$$

$$-133667$$

$$-11139$$

$$-144806 F$$

2nd Diff.

$$\begin{aligned} & 1220000 = \Delta^2_1 \\ & 60 \\ & 182 \end{aligned}$$

$$305333$$

$$50536 D$$

$$08426$$

$$06019 A$$

$$14445$$

$$\begin{aligned} & 99 \quad 59 \quad 598 \cdot 555 = \Delta^2 \\ & \underline{\underline{99 \quad 59 \quad 598 \cdot 555 = \Delta^3}} \end{aligned}$$

$$50556 D$$

$$04213$$

$$54769$$

$$383383$$

$$127794 E$$

4th Diff.

$$\begin{aligned} & + \\ & 12000000 = \Delta^4_1 \\ & 200 \\ & 533333 \end{aligned}$$

$$055556$$

$$009259 = \Delta^4$$

$$004630$$

$$035556$$

$$060186 A$$

$$333333$$

$$1666666$$

$$009259$$

$$1675925$$

$$139660 B$$

$$060185 A$$

$$421295$$

$$2949065$$

$$245755 C$$

Giving Sun's Longitude, March 13th to 25th, 1858.

No. I.

LOGARITHMS

OF

NUMBERS

FROM

1 TO 10,000,

CALCULATED, STEREOMOULDED, AND PRINTED

BY

MACHINERY.

1000	00000	1050	02119	1100	04139	1150	06070	1200	07918	1250	09691
1001	00043	1051	02160	1101	04179	1151	06108	1201	07954	1251	09726
1002	00087	1052	02202	1102	04218	1152	06145	1202	07990	1252	09760
1003	00130	1053	02243	1103	04258	1153	06183	1203	08027	1253	09795
1004	00173	1054	02284	1104	04297	1154	06221	1204	08063	1254	09830
1005	00217	1055	02325	1105	04336	1155	06258	1205	08099	1255	09864
1006	00260	1056	02366	1106	04376	1156	06296	1206	08135	1256	09899
1007	00303	1057	02407	1107	04415	1157	06333	1207	08171	1257	09934
1008	00346	1058	02449	1108	04454	1158	06371	1208	08207	1258	09968
1009	00389	1059	02490	1109	04493	1159	06408	1209	08243	1259	10003
1010	00432	1060	02531	1110	04532	1160	06446	1210	08279	1260	10037
1011	00475	1061	02572	1111	04571	1161	06483	1211	08314	1261	10072
1012	00518	1062	02612	1112	04610	1162	06521	1212	08350	1262	10106
1013	00561	1063	02653	1113	04650	1163	06558	1213	08386	1263	10140
1014	00604	1064	02694	1114	04689	1164	06595	1214	08422	1264	10175
1015	00647	1065	02735	1115	04727	1165	06633	1215	08458	1265	10209
1016	00689	1066	02776	1116	04766	1166	06670	1216	08493	1266	10243
1017	00732	1067	02816	1117	04805	1167	06707	1217	08529	1267	10278
1018	00775	1068	02857	1118	04844	1168	06744	1218	08565	1268	10312
1019	00817	1069	02898	1119	04883	1169	06781	1219	08600	1269	10346
1020	00860	1070	02938	1120	04922	1170	06819	1220	08636	1270	10380
1021	00903	1071	02979	1121	04961	1171	06856	1221	08672	1271	10415
1022	00945	1072	03019	1122	04999	1172	06893	1222	08707	1272	10449
1023	00988	1073	03060	1123	05038	1173	06930	1223	08743	1273	10483
1024	01030	1074	03100	1124	05077	1174	06967	1224	08778	1274	10517
1025	01072	1075	03141	1125	05115	1175	07004	1225	08814	1275	10551
1026	01115	1076	03181	1126	05154	1176	07041	1226	08849	1276	10585
1027	01157	1077	03222	1127	05192	1177	07078	1227	08884	1277	10619
1028	01199	1078	03262	1128	05231	1178	07115	1228	08920	1278	10653
1029	01242	1079	03302	1129	05269	1179	07151	1229	08955	1279	10687
1030	01284	1080	03342	1130	05308	1180	07188	1230	08991	1280	10721
1031	01326	1081	03383	1131	05346	1181	07225	1231	09026	1281	10755
1032	01368	1082	03423	1132	05385	1182	07262	1232	09061	1282	10789
1033	01410	1083	03463	1133	05423	1183	07298	1233	09096	1283	10823
1034	01452	1084	03503	1134	05461	1184	07335	1234	09132	1284	10857
1035	01494	1085	03543	1135	05500	1185	07372	1235	09167	1285	10890
1036	01536	1086	03583	1136	05538	1186	07408	1236	09202	1286	10924
1037	01578	1087	03623	1137	05576	1187	07445	1237	09237	1287	10958
1038	01620	1088	03663	1138	05614	1188	07482	1238	09272	1288	10992
1039	01662	1089	03703	1139	05652	1189	07518	1239	09307	1289	11025
1040	01703	1090	03743	1140	05690	1190	07555	1240	09342	1290	11059
1041	01745	1091	03782	1141	05729	1191	07591	1241	09377	1291	11093
1042	01787	1092	03822	1142	05767	1192	07628	1242	09412	1292	11126
1043	01828	1093	03862	1143	05805	1193	07664	1243	09447	1293	11160
1044	01870	1094	03902	1144	05843	1194	07700	1244	09482	1294	11193
1045	01912	1095	03941	1145	05881	1195	07737	1245	09517	1295	11227
1046	01953	1096	03981	1146	05918	1196	07773	1246	09552	1296	11260
1047	01996	1097	04021	1147	05956	1197	07809	1247	09587	1297	11294
1048	02036	1098	04060	1148	05994	1198	07846	1248	09621	1298	11327
1049	02078	1099	04100	1149	06032	1199	07882	1249	09656	1299	11361
1050	02119	1100	04139	1150	06070	1200	07918	1250	09691	1300	11394

1300	11394	1350	13033	1400	14613	1450	16137	1500	17609	1550	19033
1301	11428	1351	13066	1401	14644	1451	16167	1501	17638	1551	19061
1302	11461	1352	13098	1402	14675	1452	16197	1502	17667	1552	19089
1303	11494	1353	13130	1403	14706	1453	16227	1503	17696	1553	19117
1304	11528	1354	13162	1404	14737	1454	16256	1504	17725	1554	19145
1305	11561	1355	13194	1405	14768	1455	16286	1505	17754	1555	19173
1306	11594	1356	13226	1406	14799	1456	16316	1506	17782	1556	19201
1307	11628	1357	13258	1407	14829	1457	16346	1507	17811	1557	19229
1308	11661	1358	13290	1408	14860	1458	16376	1508	17840	1558	19257
1309	11694	1359	13322	1409	14891	1459	16406	1509	17869	1559	19285
1310	11727	1360	13354	1410	14922	1460	16435	1510	17898	1560	19312
1311	11760	1361	13386	1411	14953	1461	16465	1511	17926	1561	19340
1312	11793	1362	13418	1412	14983	1462	16495	1512	17955	1562	19368
1313	11826	1363	13450	1413	15014	1463	16524	1513	17984	1563	19396
1314	11860	1364	13481	1414	15045	1464	16554	1514	18013	1564	19424
1315	11893	1365	13513	1415	15076	1465	16584	1515	18041	1565	19451
1316	11926	1366	13545	1416	15106	1466	16613	1516	18070	1566	19479
1317	11959	1367	13577	1417	15137	1467	16643	1517	18099	1567	19507
1318	11992	1368	13609	1418	15168	1468	16673	1518	18127	1568	19535
1319	12024	1369	13640	1419	15198	1469	16702	1519	18156	1569	19562
1320	12057	1370	13672	1420	15229	1470	16732	1520	18184	1570	19590
1321	12090	1371	13704	1421	15259	1471	16761	1521	18213	1571	19618
1322	12123	1372	13735	1422	15290	1472	16791	1522	18241	1572	19645
1323	12156	1373	13767	1423	15320	1473	16820	1523	18270	1573	19673
1324	12189	1374	13799	1424	15351	1474	16850	1524	18298	1574	19700
1325	12222	1375	13830	1425	15381	1475	16879	1525	18327	1575	19728
1326	12254	1376	13862	1426	15412	1476	16909	1526	18355	1576	19756
1327	12287	1377	13893	1427	15442	1477	16938	1527	18384	1577	19783
1328	12320	1378	13925	1428	15473	1478	16967	1528	18412	1578	19811
1329	12352	1379	13956	1429	15503	1479	16997	1529	18441	1579	19838
1330	12385	1380	13988	1430	15534	1480	17026	1530	18469	1580	19866
1331	12418	1381	14019	1431	15564	1481	17056	1531	18498	1581	19893
1332	12450	1382	14051	1432	15594	1482	17085	1532	18526	1582	19921
1333	12483	1383	14082	1433	15625	1483	17114	1533	18554	1583	19948
1334	12516	1384	14114	1434	15655	1484	17143	1534	18583	1584	19976
1335	12548	1385	14145	1435	15685	1485	17173	1535	18611	1585	20003
1336	12581	1386	14176	1436	15715	1486	17202	1536	18639	1586	20030
1337	12613	1387	14208	1437	15746	1487	17231	1537	18667	1587	20058
1338	12646	1388	14239	1438	15776	1488	17260	1538	18696	1588	20085
1339	12678	1389	14270	1439	15806	1489	17289	1539	18724	1589	20112
1340	12710	1390	14301	1440	15836	1490	17319	1540	18752	1590	20140
1341	12743	1391	14333	1441	15866	1491	17348	1541	18780	1591	20167
1342	12775	1392	14364	1442	15897	1492	17377	1542	18808	1592	20194
1343	12808	1393	14395	1443	15927	1493	17406	1543	18837	1593	20222
1344	12840	1394	14426	1444	15957	1494	17435	1544	18865	1594	20249
1345	12872	1395	14457	1445	15987	1495	17464	1545	18893	1595	20276
1346	12905	1396	14489	1446	16017	1496	17493	1546	18921	1596	20303
1347	12937	1397	14520	1447	16047	1497	17522	1547	18949	1597	20330
1348	12969	1398	14551	1448	16077	1498	17551	1548	18977	1598	20358
1349	13001	1399	14582	1449	16107	1499	17580	1549	19005	1599	20385
1350	13033	1400	14613	1450	16137	1500	17609	1550	19033	1600	20412

1600	20412	1650	21748	1700	23045	1750	24304	1800	25527	1850	26717
1601	20439	1651	21775	1701	23070	1751	24329	1801	25551	1851	26741
1602	20466	1652	21801	1702	23096	1752	24353	1802	25575	1852	26764
1603	20493	1653	21827	1703	23121	1753	24378	1803	25600	1853	26788
1604	20520	1654	21854	1704	23147	1754	24403	1804	25624	1854	26811
1605	20548	1655	21880	1705	23172	1755	24428	1805	25648	1855	26834
1606	20575	1656	21906	1706	23198	1756	24452	1806	25672	1856	26858
1607	20602	1657	21932	1707	23223	1757	24477	1807	25696	1857	26881
1608	20629	1658	21958	1708	23249	1758	24502	1808	25720	1858	26905
1609	20656	1659	21985	1709	23274	1759	24527	1809	25744	1859	26928
1610	20683	1660	22011	1710	23300	1760	24551	1810	25768	1860	26951
1611	20710	1661	22037	1711	23325	1761	24576	1811	25792	1861	26975
1612	20737	1662	22063	1712	23350	1762	24601	1812	25816	1862	26998
1613	20763	1663	22089	1713	23376	1763	24625	1813	25840	1863	27021
1614	20790	1664	22115	1714	23401	1764	24650	1814	25864	1864	27045
1615	20817	1665	22141	1715	23426	1765	24674	1815	25888	1865	27068
1616	20844	1666	22167	1716	23452	1766	24699	1816	25912	1866	27091
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1637	21405	1687	22712	1737	23980	1787	25212	1837	26411	1887	27577
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1644	21590	1694	22891	1744	24155	1794	25382	1844	26576	1894	27738
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1647	21669	1697	22968	1747	24229	1797	25455	1847	26647	1897	27807
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9125	96023	9175	96261	9225	96497	9275	96731	9325	96965	9375	97197
9126	96028	9176	96265	9226	96501	9276	96736	9326	96970	9376	97202
9127	96033	9177	96270	9227	96506	9277	96741	9327	96974	9377	97206
9128	96038	9178	96275	9228	96511	9278	96745	9328	96979	9378	97211
9129	96042	9179	96280	9229	96515	9279	96750	9329	96984	9379	97216
9130	96047	9180	96284	9230	96520	9280	96755	9330	96988	9380	97220
9131	96052	9181	96289	9231	96525	9281	96759	9331	96993	9381	97225
9132	96057	9182	96294	9232	96530	9282	96764	9332	96997	9382	97230
9133	96061	9183	96298	9233	96534	9283	96769	9333	97002	9383	97234
9134	96066	9184	96303	9234	96539	9284	96774	9334	97007	9384	97239
9135	96071	9185	96308	9235	96544	9285	96778	9335	97011	9385	97243
9136	96076	9186	96313	9236	96548	9286	96783	9336	97016	9386	97248
9137	96080	9187	96317	9237	96553	9287	96788	9337	97021	9387	97253
9138	96085	9188	96322	9238	96558	9288	96792	9338	97025	9388	97257
9139	96090	9189	96327	9239	96562	9289	96797	9339	97030	9389	97262
9140	96095	9190	96332	9240	96567	9290	96802	9340	97035	9390	97267
9141	96099	9191	96336	9241	96572	9291	96806	9341	97039	9391	97271
9142	96104	9192	96341	9242	96577	9292	96811	9342	97044	9392	97276
9143	96109	9193	96346	9243	96581	9293	96816	9343	97049	9393	97280
9144	96114	9194	96350	9244	96586	9294	96820	9344	97053	9394	97285
9145	96118	9195	96355	9245	96591	9295	96825	9345	97058	9395	97290
9146	96123	9196	96360	9246	96595	9296	96830	9346	97063	9396	97294
9147	96128	9197	96365	9247	96600	9297	96834	9347	97067	9397	97299
9148	96133	9198	96369	9248	96605	9298	96839	9348	97072	9398	97304
9149	96137	9199	96374	9249	96609	9299	96844	9349	97077	9399	97308
9150	96142	9200	96379	9250	96614	9300	96848	9350	97081	9400	97313

9400	97313	9450	97543	9500	97772	9550	98000	9600	98227	9650	98453
9401	97317	9451	97548	9501	97777	9551	98005	9601	98232	9651	98457
9402	97322	9452	97552	9502	97782	9552	98009	9602	98236	9652	98462
9403	97327	9453	97557	9503	97786	9553	98014	9603	98241	9653	98466
9404	97331	9454	97562	9504	97791	9554	98019	9604	98245	9654	98471
9405	97336	9455	97566	9505	97795	9555	98023	9605	98250	9655	98475
9406	97340	9456	97571	9506	97800	9556	98028	9606	98254	9656	98480
9407	97345	9457	97575	9507	97804	9557	98032	9607	98259	9657	98484
9408	97350	9458	97580	9508	97809	9558	98037	9608	98263	9658	98489
9409	97354	9459	97585	9509	97813	9559	98041	9609	98268	9659	98493
9410	97359	9460	97589	9510	97818	9560	98046	9610	98272	9660	98498
9411	97364	9461	97594	9511	97823	9561	98050	9611	98277	9661	98502
9412	97368	9462	97598	9512	97827	9562	98055	9612	98281	9662	98507
9413	97373	9463	97603	9513	97832	9563	98059	9613	98286	9663	98511
9414	97377	9464	97607	9514	97836	9564	98064	9614	98290	9664	98516
9415	97382	9465	97612	9515	97841	9565	98068	9615	98295	9665	98520
9416	97387	9466	97617	9516	97845	9566	98073	9616	98299	9666	98525
9417	97391	9467	97621	9517	97850	9567	98078	9617	98304	9667	98529
9418	97396	9468	97626	9518	97855	9568	98082	9618	98308	9668	98534
9419	97400	9469	97630	9519	97859	9569	98087	9619	98313	9669	98538
9420	97405	9470	97635	9520	97864	9570	98091	9620	98318	9670	98543
9421	97410	9471	97640	9521	97868	9571	98096	9621	98322	9671	98547
9422	97414	9472	97644	9522	97873	9572	98100	9622	98327	9672	98552
9423	97419	9473	97649	9523	97877	9573	98105	9623	98331	9673	98556
9424	97424	9474	97653	9524	97882	9574	98109	9624	98336	9674	98561
9425	97428	9475	97658	9525	97886	9575	98114	9625	98340	9675	98565
9426	97433	9476	97663	9526	97891	9576	98118	9626	98345	9676	98570
9427	97437	9477	97667	9527	97896	9577	98123	9627	98349	9677	98574
9428	97442	9478	97672	9528	97900	9578	98127	9628	98354	9678	98579
9429	97447	9479	97676	9529	97905	9579	98132	9629	98358	9679	98583
9430	97451	9480	97681	9530	97909	9580	98137	9630	98363	9680	98588
9431	97456	9481	97685	9531	97914	9581	98141	9631	98367	9681	98592
9432	97460	9482	97690	9532	97918	9582	98146	9632	98372	9682	98597
9433	97465	9483	97695	9533	97923	9583	98150	9633	98376	9683	98601
9434	97470	9484	97699	9534	97928	9584	98155	9634	98381	9684	98605
9435	97474	9485	97704	9535	97932	9585	98159	9635	98385	9685	98610
9436	97479	9486	97708	9536	97937	9586	98164	9636	98390	9686	98614
9437	97483	9487	97713	9537	97941	9587	98168	9637	98394	9687	98619
9438	97488	9488	97717	9538	97946	9588	98173	9638	98399	9688	98623
9439	97493	9489	97722	9539	97950	9589	98177	9639	98403	9689	98628
9440	97497	9490	97727	9540	97955	9590	98182	9640	98408	9690	98632
9441	97502	9491	97731	9541	97959	9591	98186	9641	98412	9691	98637
9442	97506	9492	97736	9542	97964	9592	98191	9642	98417	9692	98641
9443	97511	9493	97740	9543	97968	9593	98195	9643	98421	9693	98646
9444	97516	9494	97745	9544	97973	9594	98200	9644	98426	9694	98650
9445	97520	9495	97749	9545	97978	9595	98204	9645	98430	9695	98655
9446	97525	9496	97754	9546	97982	9596	98209	9646	98435	9696	98659
9447	97529	9497	97759	9547	97987	9597	98214	9647	98439	9697	98664
9448	97534	9498	97763	9548	97991	9598	98218	9648	98444	9698	98668
9449	97539	9499	97768	9549	97996	9599	98223	9649	98448	9699	98673
9450	97543	9500	97772	9550	98000	9600	98227	9650	98453	9700	98677

9700	98677	9750	98900	9800	99123	9850	99344	9900	99564	9950	99782
9701	98682	9751	98905	9801	99127	9851	99348	9901	99568	9951	99787
9702	98686	9752	98909	9802	99131	9852	99352	9902	99572	9952	99791
9703	98691	9753	98914	9803	99136	9853	99357	9903	99577	9953	99795
9704	98695	9754	98918	9804	99140	9854	99361	9904	99581	9954	99800
9705	98700	9755	98923	9805	99145	9855	99366	9905	99585	9955	99804
9706	98704	9756	98927	9806	99149	9856	99370	9906	99590	9956	99808
9707	98709	9757	98932	9807	99154	9857	99374	9907	99594	9957	99813
9708	98713	9758	98936	9808	99158	9858	99379	9908	99599	9958	99817
9709	98717	9759	98941	9809	99162	9859	99383	9909	99603	9959	99822
9710	98722	9760	98945	9810	99167	9860	99388	9910	99607	9960	99826
9711	98726	9761	98949	9811	99171	9861	99392	9911	99612	9961	99830
9712	98731	9762	98954	9812	99176	9862	99396	9912	99616	9962	99835
9713	98735	9763	98958	9813	99180	9863	99401	9913	99621	9963	99839
9714	98740	9764	98963	9814	99185	9864	99405	9914	99625	9964	99843
9715	98744	9765	98967	9815	99189	9865	99410	9915	99629	9965	99848
9716	98749	9766	98972	9816	99193	9866	99414	9916	99634	9966	99852
9717	98753	9767	98976	9817	99198	9867	99419	9917	99638	9967	99856
9718	98758	9768	98981	9818	99202	9868	99423	9918	99642	9968	99861
9719	98762	9769	98985	9819	99207	9869	99427	9919	99647	9969	99865
9720	98767	9770	98989	9820	99211	9870	99432	9920	99651	9970	99870
9721	98771	9771	98994	9821	99216	9871	99436	9921	99656	9971	99874
9722	98776	9772	98998	9822	99220	9872	99441	9922	99660	9972	99878
9723	98780	9773	99003	9823	99224	9873	99445	9923	99664	9973	99883
9724	98784	9774	99007	9824	99229	9874	99449	9924	99669	9974	99887
9725	98789	9775	99012	9825	99233	9875	99454	9925	99673	9975	99891
9726	98793	9776	99016	9826	99238	9876	99458	9926	99677	9976	99896
9727	98798	9777	99021	9827	99242	9877	99463	9927	99682	9977	99900
9728	98802	9778	99025	9828	99247	9878	99467	9928	99686	9978	99904
9729	98807	9779	99029	9829	99251	9879	99471	9929	99691	9979	99909
9730	98811	9780	99034	9830	99255	9880	99476	9930	99695	9980	99913
9731	98816	9781	99038	9831	99260	9881	99480	9931	99699	9981	99917
9732	98820	9782	99043	9832	99264	9882	99484	9932	99704	9982	99922
9733	98825	9783	99047	9833	99269	9883	99489	9933	99708	9983	99926
9734	98829	9784	99052	9834	99273	9884	99493	9934	99712	9984	99930
9735	98834	9785	99056	9835	99277	9885	99498	9935	99717	9985	99935
9736	98838	9786	99061	9836	99282	9886	99502	9936	99721	9986	99939
9737	98843	9787	99065	9837	99286	9887	99506	9937	99726	9987	99944
9738	98847	9788	99069	9838	99291	9888	99511	9938	99730	9988	99948
9739	98851	9789	99074	9839	99295	9889	99515	9939	99734	9989	99952
9740	98856	9790	99078	9840	99300	9890	99520	9940	99739	9990	99957
9741	98860	9791	99083	9841	99304	9891	99524	9941	99743	9991	99961
9742	98865	9792	99087	9842	99308	9892	99528	9942	99747	9992	99965
9743	98869	9793	99092	9843	99313	9893	99533	9943	99752	9993	99970
9744	98874	9794	99096	9844	99317	9894	99537	9944	99756	9994	99974
9745	98878	9795	99100	9845	99322	9895	99542	9945	99760	9995	99978
9746	98883	9796	99105	9846	99326	9896	99546	9946	99765	9996	99983
9747	98887	9797	99109	9847	99330	9897	99550	9947	99769	9997	99987
9748	98892	9798	99114	9848	99335	9898	99555	9948	99774	9998	99991
9749	98896	9799	99118	9849	99339	9899	99559	9949	99778	9999	99996
9750	98900	9800	99123	9850	99344	9900	99564	9950	99782	10000	00000

SPECIMENS
OF
VARIOUS TABLES.

No. 2.

$$u = x^4 - 6x^3 + 11x^2 - 6x$$

x	u
0	0
1	0
2	0
3	0
4	24
5	120
6	360
7	840
8	1680
9	3024
10	5040
11	7920
12	11880
13	17160
14	24024
15	32760
16	43680
17	57120
18	73440
19	93024
20	116280
21	143640
22	175560
23	212520
24	255024
25	303600
26	358800
27	421200
28	491400
29	570024
30	657720
31	755160
32	863040
33	982080
34	1113024
35	1256640
36	1413720
37	1585080
38	1771560
39	1974024
40	2193360
41	2430480
42	2686320
43	2961840
44	3258024
45	3575880
46	3916440
47	4280760
48	4669920
49	5085024
50	5527200

No. 3.

$$u = x^4 - 72x^3 + 1798x^2 - 18072x$$

x	u
0	0
1	16345
2	29512
3	39897
4	47872
5	53785
6	57960
7	60697
8	62272
9	62937
10	62920
11	62425
12	61632
13	60697
14	59752
15	58905
16	58240
17	57817
18	57672
19	57817
20	58240
21	58905
22	59752
23	60697
24	61632
25	62425
26	62920
27	62937
28	62272
29	60697
30	57960
31	53785
32	47872
33	39897
34	29512
35	16345
36	00000

No. 4.		No. 5.		No. 6.	
Num.	Log.	Num.	Log.	Log. Tan. 27° 00'	
1100	3.0413927	7600	3.8808136	"	0
1101	3.0417873	7601	3.8808707		1
1102	3.0421816	7602	3.8809279		2
1103	3.0425755	7603	3.8809850		3
1104	3.0429691	7604	3.8810421		4
1105	3.0433623	7605	3.8810992		5
1106	3.0437551	7606	3.8811563		6
1107	3.0441476	7607	3.8812134		7
1108	3.0445398	7608	3.8812705		8
1109	3.0449315	7609	3.8813276		9
1110	3.0453230	7610	3.8813847		10
1111	3.0457141	7611	3.8814417		11
1112	3.0461048	7612	3.8814988		12
1113	3.0464952	7613	3.8815558		13
1114	3.0468852	7614	3.8816129		14
1115	3.0472749	7615	3.8816699		15
1116	3.0476642	7616	3.8817269		16
1117	3.0480532	7617	3.8817840		17
1118	3.0484418	7618	3.8818410		18
1119	3.0488301	7619	3.8818980		19
1120	3.0492180	7620	3.8819550		20
1121	3.0496056	7621	3.8820120		21
1122	3.0499929	7622	3.8820689		22
1123	3.0503798	7623	3.8821259		23
1124	3.0507663	7624	3.8821829		24
1125	3.0511525	7625	3.8822398		25
1126	3.0515384	7626	3.8822968		26
1127	3.0519239	7627	3.8823537		27
1128	3.0523091	7628	3.8824107		28
1129	3.0526939	7629	3.8824676		29
1130	3.0530784	7630	3.8825245		30
1131	3.0534626	7631	3.8825815		31
1132	3.0538464	7632	3.8826384		32
1133	3.0542299	7633	3.8826953		33
1134	3.0546131	7634	3.8827522		34
1135	3.0549959	7635	3.8828090		35
1136	3.0553783	7636	3.8828659		36
1137	3.0557605	7637	3.8829228		37
1138	3.0561423	7638	3.8829797		38
1139	3.0565237	7639	3.8830365		39
1140	3.0569049	7640	3.8830934		40
1141	3.0572856	7641	3.8831502		41
1142	3.0576661	7642	3.8832070		42
1143	3.0580462	7643	3.8832639		43
1144	3.0584260	7644	3.8833207		44
1145	3.0588055	7645	3.8833775		45
1146	3.0591846	7646	3.8834343		46
1147	3.0595634	7647	3.8834911		47
1148	3.0599419	7648	3.8835479		48
		7649	3.8836047		49
					50

No. 7.		No. 8.		No. 9.	
Log. sin. 1° 00'		Log. sin. 45° 00'		Sin.	Arc.
"	"	"	"	0.230	13 17 40.5
0	8.2418553	0	9.8494850	231	13 21 21.4
1	8.2419759	1	9.8494871	232	13 24 53.5
2	8.2420965	2	9.8494892	233	13 28 25.5
3	8.2422170	3	9.8494913	234	13 31 57.7
4	8.2423376	4	9.8494934	235	13 35 29.8
5	8.2424580	5	9.8494955	236	13 39 02.1
6	8.2425785	6	9.8494976	237	13 42 34.4
7	8.2426989	7	9.8494997	238	13 46 06.7
8	8.2428192	8	9.8495018	239	13 49 39.1
9	8.2429396	9	9.8495040	240	13 53 11.5
10	8.2430599	10	9.8495061	241	13 56 44.0
11	8.2431802	11	9.8495082	242	14 00 16.6
12	8.2433004	12	9.8495103	243	14 03 49.2
13	8.2434206	13	9.8495124	244	14 07 21.9
14	8.2435408	14	9.8495145	245	14 10 54.6
15	8.2436609	15	9.8495166	246	14 14 27.4
16	8.2437810	16	9.8495187	247	14 18 00.2
17	8.2439011	17	9.8495208	248	14 21 33.1
18	8.2440212	18	9.8495229	249	14 25 06.0
19	8.2441412	19	9.8495250	250	14 28 39.0
20	8.2442611	20	9.8495271	251	14 32 12.1
21	8.2443811	21	9.8495292	252	14 35 45.2
22	8.2445010	22	9.8495313	253	14 39 18.4
23	8.2446209	23	9.8495334	254	14 42 51.6
24	8.2447407	24	9.8495355	255	14 46 24.9
25	8.2448605	25	9.8495376	256	14 49 58.3
26	8.2449803	26	9.8495397	257	14 53 31.7
27	8.2451000	27	9.8495418	258	14 57 05.1
28	8.2452198	28	9.8495439	259	15 00 38.6
29	8.2453394	29	9.8495461	260	15 04 12.2
30	8.2454591	30	9.8495482	261	15 07 45.9
31	8.2455787	31	9.8495503	262	15 11 19.6
32	8.2456983	32	9.8495524	263	15 14 53.3
33	8.2458178	33	9.8495545	264	15 18 27.1
34	8.2459373	34	9.8495566	265	15 22 01.0
35	8.2460568	35	9.8495587	266	15 25 35.0
36	8.2461762	36	9.8495608	267	15 29 09.0
37	8.2462957	37	9.8495629	268	15 32 43.0
38	8.2464150	38	9.8495650	269	15 36 17.2
39	8.2465344	39	9.8495671	270	15 39 51.4
40	8.2466537	40	9.8495692		
41	8.2467730	41	9.8495713		
42	8.2468922	42	9.8495734		
43	8.2470115	43	9.8495755		
44	8.2471306	44	9.8495776		
45	8.2472498	45	9.8495797		
46	8.2473689	46	9.8495818		
47	8.2474880	47	9.8495839		
48	8.2476071	48	9.8495860		
49	8.2477261	49	9.8495881		
50	8.2478451	50	9.8495903		

No. 10.

Ranges of Shot with various Charges.

Powder Range.

10	53,000
11	77,712
12	102,776
13	128,184
14	153,928
15	180,000
16	206,392
17	233,096
18	260,104
19	287,408
20	315,000
21	342,872
22	371,016
23	399,424
24	428,088
25	457,000
26	486,152
27	515,536
28	545,144
29	574,968
30	605,000
31	635,232
32	665,656
33	696,264
34	727,048
35	758,000
36	789,112
37	820,376
38	851,784
39	883,328
40	915,000

No. 11.

Log. Value of Male Life in London.

Age. Log.

78	5.8090091
77	5.8561847
76	5.8997276
75	5.9398879
74	5.9769054
73	6.0110100
72	6.0424209
71	6.0713475
70	6.0979887
69	6.1225332
68	6.1451596
67	6.1660361
66	6.1853207
65	6.2031612
64	6.2196953
63	6.2350502
62	6.2493431
61	6.2626807
60	6.2751598
59	6.2868666
58	6.2978775
57	6.3082582
56	6.3180644
55	6.3273418
54	6.3361253
53	6.3444401
52	6.3523008

No. 12.

VENUS.

Mean Time.

1858	Day of the Month.	Heliocentric. Log. of Rad. Vect. Noon.
Jan.	11	9.8613809
	12	9.8614394
	13	9.8614963
	14	9.8615516
	15	9.8616051
	16	9.8616569
	17	9.8617069
	18	9.8617551
	19	9.8618014
	20	9.8618458
	21	9.8618883
	22	9.8619288
	23	9.8619673
	24	9.8620037
	25	9.8620381
	26	9.8620704
	27	9.8621006
	28	9.8621287
	29	9.8621545
	30	9.8621783
	31	9.8621908
Feb.	1	9.8622191
	2	9.8622362
	3	9.8622511
	4	9.8622637
	5	9.8622741
	6	9.8622822
	7	9.8622880
	8	9.8622916
	9	9.8622929
	10	9.8622920
	11	9.8622888
	12	9.8622833

No. 13.

1858	Day of the Month.	The Sun's Apparent Longitude. Noon.
March	7	346 39 20.4
	8	347 39 17.0
	9	348 39 12.3
	10	349 39 06.0
	11	350 38 58.2
	12	351 38 48.5
	13	352 38 37.1
	14	353 38 23.7
	15	354 38 08.4
	16	355 37 50.9
	17	356 37 31.3
	18	357 37 09.6
	19	358 36 45.6
	20	350 36 19.4
	21	0 35 50.8
	22	1 35 20.0
	23	2 34 46.9
	24	3 34 11.4
	25	4 33 33.7
	26	5 32 53.7
	27	6 32 11.5
	28	7 31 27.1
	29	8 30 40.5
	30	9 29 51.9
	31	10 29 01.2
April	1	11 28 08.6
	2	12 27 14.1
	3	13 26 17.9

No. 14.

Mean Time.

1858	Day of the Month.	Logarithm of the Rad. Vect. of the Earth. Noon.
March	7	9.996956
	8	9.997075
	9	9.997195
	10	9.997314
	11	9.997434
	12	9.997554
	13	9.997675
	14	9.997795
	15	9.997915
	16	9.998036
	17	9.998156
	18	9.998277
	19	9.998398
	20	9.998518
	21	9.998639
	22	9.998760
	23	9.998881
	24	9.999002
	25	9.999124
	26	9.999247
	27	9.999369
	28	9.999493
	29	9.999618
	30	9.999743
	31	9.999870

No. 15.

MARS.

Mean Time.

1858	Day of the Month.	Geocentric. Log. of True Dist. from the Earth. Noon.
March	18	9.937484
	19	9.932978
	20	9.928458
	21	9.923924
	22	9.919377
	23	9.914819
	24	9.910251
	25	9.905673
	26	9.901087
	27	9.896495
	28	9.891897
	29	9.887295
	30	9.882690

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